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ARTICLE

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A SECURE IOT-BLOCKCHAIN INFRASTRUCTURE FOR ENHANCED TRACEABILITY AND DATA INTEGRITY IN MODERN SUPPLY CHAINS

SUBHADIP NANDI*

Agriculture and husbandry are both crucial for financial robustness, while assuring that food is safe and also that supply chain transparency is extremely important. The vast data generated by IoT and blockchain can be analyzed in a very efficient way with the help of sophisticated deep learning technique. This article makes use of the secure IoT-blockchain data from Industry 4.0 and presents a recurrent hybrid neural network model that consists of a combination of LSTM and GRU, which is optimized through a genetic algorithm. The system predicts the trends, makes the provenance more transparent, and provides support for better decisions in the supply chain. The performance was assessed for various user groups in order to help further steps of the adoption by the industry and the development of the policy.

Introduction

Wireless technologies, sensors, and smart machines have come together in the age of the Internet of Things (IoT) to make connected enterprises a reality. The Industrial Internet of Things is the one that takes charge of the processes, machinery, and supply data. Nevertheless, food safety continues to be one of the main worldwide concerns while governments are taking measures to intensify tracking and identification of agricultural products. The use of ICT tools such as unmanned aerial vehicles, robots, and remote sensing for monitoring, irrigation, and crop management have revolutionized these activities. Blockchain, which was invented for Bitcoin, has now become a great platform for the supply chain, and by being transparent, secure, and having records that are immutable it helps in the prevention of fraud, contamination, and logistical issues in the food industry[1]. To improve food traceability, the current work presents a hybrid LSTM (Long Short-Term Memory)–GRU (Gated Recurrent Unit) model that is structured using a genetic algorithm and supported by an IoT–blockchain ledger with these digital technologies made suitable for accurate traceability and demand forecasting of meats and foods in the current supply-chain system.

* Assistant Professor, Department of Computational Sciences, Brainware University, Kolkata, India
e-mail: subhadippaper@gmail.com

Literature Review

According to new research reports, the need for IoT and blockchain is increasing if we want to have a fully transparent and traceable food supply chain. IoT sensors provide insight into the environment and logistics operations in a continuous manner, while the use of blockchain offers unchangeable data sharing among the involved parties. Earlier studies were dealing with RFID-based traceability, double-chain storage models along with the use of consortium blockchain frameworks in order to overcome the encountered issues of data security and provenance[2]. In addition, demand prediction has been done by the help of sophisticated deep learning models which have proven to be of much help in modern agro-food supply chain system optimization.

IoT and Blockchainin Food Industry

The traceability of agricultural products is one of the main factors when it comes to food safety, however, the supply chain is spread out through many different entities that are using data systems that cannot connect with each other. This situation makes it a lot harder to do centralized tracking. The solution to this problem is IoT-Blockchain which not only brings to the table the benefit of the trustless nature of the network but it also enables real-time data sharing, secure data storage, and automated verification. The smart agriculture ecosystem revolves around the input of data by the stakeholders through smartphone devices, with IoT devices monitoring and collecting environmental data such as temperature, humidity, soil pH, and moisture[3]. The blockchain method is used to secure the data with the help of hashing, signing, and then storing it across many nodes making it a secure and transparent system. Such a pairing of technologies serves the purpose of giving full protection to the products and thus letting the consumers know who made the product of their choice and hence allowing them to trace the product back to the source by simply scanning the barcode. The use of the blockchain also makes it possible to carry out and verify the payments while cutting out the middleman. Moreover, blockchain technology is indispensable for managing secure multi-layer storage setups and RFID-supported traceability models[4].

System Model

Organic farming is substantially better than conventional farming in many ways, including soil and water quality, animal well-being, and the environment. It involves numerous elements like farmers, warehouses, retailers, and consumers, which can follow a streamlined process throughout the chain. Meat processing and distribution are part of the warehouse's operations. In the proposed IoT-blockchain system, the roles of the Administrators are to activate, identify, and link up the participants, while for Farmers, they are to put tags on and provide the animals' data to the system, and for Warehouses–to make the whole process of registering the slaughtering, weighing, and packing and branding activities and chain of responsibility more precise. Every single part of the meat is traced with a barcode, and all this vast amount of information is stored on the blockchain. Products will come to retailers from the distribution unit, but, at the same time, farmers can deliver live animals to retailers. By the same token, Consumers who could be either restaurants or individuals, as well as the retail side, can both have access to the blockchain and be able to trace back the meat origin by scanning tags or using the serial number, thus, making a complete and transparent management system.

Proposed Solution

In order to make a provenance system suitable for the food supply chain of Industry 4.0, IoT, blockchain, and deep learning are combined. The system uses Hyperledger Fabric. Livestock data is recorded, processing and packaging details are logged by the warehouse, and production is tracked at the distribution level through barcodes, GPS, and temperature sensors. Any kind of information and data are securely stored within a private blockchain which makes it possible to reach the full path of the product from the manufacturer to the customer. By reading the tags, consumers are able to see product details and origin. The implementation is done by using digital signatures, contracts, and peers as well to make the sharing of data over secure channels and in a tamper-proof way where each block has the multiple records which are hashed, encrypted and timed.

Advanced Deep Learning and Genetic Algorithm

The Hybrid Supply Chain Model adopts the use of recurrent neural networks established by the combination of LSTM and GRU which aim to increase the accuracy of predictions. The Genetic Algorithm is employed to adjust the hyperparameters including the initial weights, the number of layers, the size of neurons, and the epochs. The blockchain data has been separted into the training and testing sets. For each LSTM and GRU, meta-learner will take the outputs from both of them and operate on them independently. GA calculates the RMSE as a measure of the fitness and technology the is print improving the solutions through a selection, crossover, and mutation process. When it comes to the slightly higher range of the PSO, the PSO was ruled out by GA, even though, the GA was popularly known for its verbose performance.

Conclusion

This article presents an IoT–blockchain–deep learning provenance system that ensures food traceability, accurate demand forecasting, and secure transactions. Performance tests with up to 800 users showed stable latency and resource use. Future work will explore more complex business networks. ❐

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